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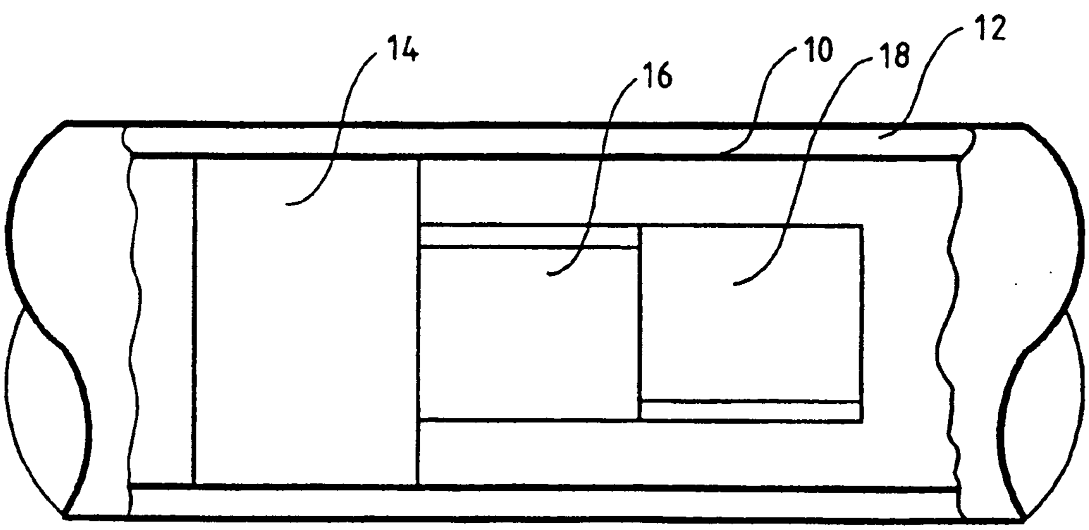

(57) Abstract

The present invention relates to a method and apparatus for treating material which conducts heat poorly, in which method the material is fed to a flowing channel of an indirect heat exchanger, in which channel the average velocity of the material is kept below 5 m/s, preferably below 1.0 m/s.

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METHOD AND APPARATUS FOR TREATING MATERIAL WHICH CONDUCTS HEAT POORLY

The present invention relates to a method and an apparatus for treating material which conducts heat poorly. The method and apparatus in accordance with the invention are especially suitable for treating medium-consistency fibre suspensions of the wood-processing industry, more generally for treating pulp. In particular, the method and apparatus in accordance with the invention are related to heating or recovering heat from pulp having a consistency of 5 - 20 %, preferably 6 - 16 %. For example, the method in accordance with the invention may be applied to treating pulp for a bleaching process to be carried out at a raised temperature. Such bleaching processes using high temperatures include oxygen and peroxide bleaching, for instance.

It is known that for the above-mentioned purposes, i.e. for heating pulp for bleaching, for example, steam is used by means of which the pulp is heated directly. A process like this functions in such a way that the pulp is fed to a steam feeding device by means of a pump, in which feeding device the temperature of the pulp may be raised as much as desired by feeding steam directly into the pulp. After the mixing of steam, the pulp is led into a mixer, by means of which not only are the possible temperature variations resulting from the mixing of the steam equalized but the desired bleaching chemical/s is/are also mixed into the pulp. From the mixer the pulp is led further into a reaction tower, in which the bleaching reaction itself is allowed to happen. For example, in peroxide bleaching the temperature in the tower is maintained at about 100 °C and the pressure in the bottom portion of the tower at about 10 - 8 bar and in the top portion of the tower at about 5 - 3 bar. The pulp is withdrawn from the tower into a blow tank by

means of a withdrawing device, in which blow tank the st am still present in the pulp is separated from the pulp to the top portion of the blow tank, and from which the pulp is withdrawn by means of a pump. The steam separated to the top portion of the blow tank is led to a condenser, in which the heat still present in the steam is recovered, whereby condensation water is generated.

However, there are a few disadvantages in the process described above.

- For the first, a large part of the steam is condensated into the pulp, whereby the consistency of the pulp is no longer what it was when exiting from the pump. For example, raising the temperature by 20 °C by direct steam decreases the consistency approximately 0.5 %, which, in some cases, causes definite problems in the process.
- For the second, the pressure in the steam feeder needs to be limited to about 9 - 10 bar, since steam having higher pressure is not always available (depending on the mill conditions), or at least it is not always possible to easily conduct such steam to the bleach plant. Thus, also the processing pressure in the reactor tower is limited to the above-mentioned value.
- For the third, a large blow tank-pump-condenser combination is required for recovering heat and for leading the pulp to the next process stage.
- For the fourth, the highest temperature of the condenser is 100 °C, since the pressure is decreased to outdoor air pressure.
- For the fifth, the condensation water from the condenser is foul, since it contains residues of both bleaching chemicals and reaction products of bleaching.

- For the sixth, the high pressure steam caus s significant costs for a cellulose mill. If a smaller amount of high pressure steam was required, it could be possible to sell a corresponding amount of energy to power companies, for example.

All the above-mentioned problems will be solved if an indirect heat exchanger can be developed which is suitable for use with thick stock. In other words, an apparatus being able to both heat and cool thick stock which tends to flow as a uniform fibre net, a so called plug. Such so called MC heat exchangers have been dealt with at least in FI patent application 781789 and FI patents 67584 and 78131.

In the Finnish patent application 781789, a great number of apparatus arrangements exploiting and applying fluidization of thick stock are presented. However, the publication is based on a fluidization theory developed just recently, which theory has been during the following two decades observed to be a good basis for further development, but which did not at the time, i.e. at the beginning of the 1970's, lead to any other practical applications than to a so called MC pump. In other words, the various applications presented were at the stage of a rough idea requiring a great deal of further research with respect to each individual apparatus, which research has, depending on the case, led to either development of the apparatus to a commercial product or rejection of the idea as unfeasible. The indirect heat exchanger disclosed in the patent application is intended to operate in such a way that the casing of a tubular apparatus is encircled with heat exchange channels and forms a heat exchange surface. Inside the tube at the heat exchange surfaces there is a rotor, by means of which the fibre suspension flowing in the tube is fluidized. The idea is that a

strong turbulence is able to make every pulp particle circulate so close to the heat exchange surface that the temperature thereof could change, depending naturally on whether one wishes to recover heat from pulp or to heat pulp. It is not known by us whether such an apparatus has ever been experimented. In the light of what is currently known, it is obvious that the apparatus will work, provided that the flow velocity in the tube is slow enough. Yet, the idea has two weaknesses. Firstly, a long treatment of pulp with a fluidizer necessarily affects the technical paper properties of the pulp, such as the strength or the average length of the fibres. Secondly, fluidization results in such great energy consumption that a heat exchanger based on mechanical fluidizing can never become a product accepted by cellulose mills.

FI patent 78131 is related to a heat exchanger which is relatively small in size and intended to be located before the bleaching tower or after that, for example, to either heat pulp or to recover heat from it. It is essential for the apparatus disclosed in the patent that a fluidizing apparatus is arranged on the inlet side of the heat exchange surfaces, by means of which apparatus the pulp is made flow through the relatively narrow passes of the compact heat exchanger. One problem with such a heat exchanger is the fluidizer that is the basic requirement for the opeartion thereof, being an apparatus that consumes a great deal of energy. Also, such a construction is unsuitable for use in a large bleaching tower, the diameter of which is approximately 5 - 10 meters. It is out of the question that in a tank as large as that, fluidization of the pulp could be effected in such a way that it would cover the whole cross-sectional area of the tank, as described in the FI patent. The energy consumption would be enormous, and on the other hand, several fluidizers would have to be used, whereby there would necessarily be problems with

constructions. Also, one obvious problem is the fact that while no precise dimensioning instructions for the heat exchanger are given in the publication, the pulp in the heat exchange channels will form a fibre net and the pulp will be unable to discharge from the apparatus, or that the pulp will not heat in the apparatus in a desired way, after all.

The greatest disadvantage of both apparatuses described above is the energy consumption thereof, which is due to the fluidizers which are intended to be used continuously in the apparatuses. To eliminate said problem, the apparatus should thus be primarily based on the plug flow of the pulp.

An arrangement applying the above-mentioned plug flow is described in FI patent 67584, in which arrangement there are heat exchange surfaces arranged in connection with the wall of a bleaching tower. In other words, the publication conveys the idea that pulp could be heated or cooled in the bleaching tower. However, the application disclosed in the publication is unfeasible, because it simply cannot work. It is impossible to heat the whole of the pulp by heating the surface layer, as thick stock rises or falls as a uniform pillar in a bleaching tower having a diameter of several meters. If the intention is to make the temperature of the pulp rise in the whole tower by raising the temperature of the surface only, the arrangement will only result in enormous temperature variations.

In FI patent application 943001, which became public on December 22, 1995, various alternatives for arrangement of an indirect heat exchanger inside a reactor tower are presented. Unlike in the above-mention d FI pat nt 67584, a heat exchanger is composed of concentrical annular heat exchange elements arranged inside the reactor tower, to

which elements the heat exchange medium, preferably steam, is conducted. Each heat exchange element is preferably composed of two concentric cylindrical casings, which have been connected to each other at their ends by means of end surfaces. Through the closed annular space formed hereby, the heat exchange medium flows from the inlet to the outlet, heating at the same time both the casing surfaces and the pulp gliding along the outer surface thereof. The heat exchange elements are connected to each other preferably adjacent the upper edges thereof, preferably by means of radial channels through which the heat exchange medium is led to all annular elements. Simultaneously, said channels function as supporters of the heat exchange elements. Preferably, the lower edges of the heat exchange elements on the opposite side of the tower are connected to each other by means of channels, through which the condensed steam and the condensation water are conducted out of the elements and out of the tower.

As one embodiment of the above-mentioned Finnish application, it is shown how the surface of the elements does not have to be even, but how it may as well be corrugated in the way indicated in a figure. The intention is to improve heating of the pulp in the annular flow channels between the elements by causing turbulence into the pulp, which turbulence mixes the pulp particles moving along the surface of the elements with particles moving further away in the channels. Further, in another embodiment, it is presented how the heat exchange elements, the outermost of which is located in connection with the wall of the reactor tower, are provided with either peripheral annular ribs or spiral ribs on the outer surface facing the pulp. The purpose of the ribs is to cause some turbulence in the flowing pulp, so that the pulp having heated on the surface of the elements would mix with the pulp flowing further away

from the surface of the elements, whereby the pulp would heat more uniformly.

In the above-mentioned FI application 943001, it is also observed that by means of the turbulence or the like that is brought about by said ribs arranged on the heat exchange surfaces, it is not possible to conduct heat very far from the heat exchange surfaces, but the distance will, in practice, be 50 - 200 mm only, depending on the strength of the turbulence, and the velocity and consistency of the pulp. According to said application, from this follows that the heat exchange surfaces, i.e. the elements, should be located at a distance of about 200 - 250 mm from each other. Often, however, this will not work in practice, since the flow resistance generated by the heat exchange surfaces would be too great. As another solution, more than one heat exchangers are arranged one after another in the direction of the flow in the reactor tower. The heat exchangers are arranged in such a way, for example, that the diameters of the heat exchange elements of one heat exchanger form a sequence of 650 mm, 1150 mm, 1650 mm, 2150 mm, and so on. The sequence of the diameters in the other heat exchanger is correspondligly 400 mm, 900 mm, 1400 mm, 1900 mm, 2400 mm, and so on. In other words, pulp rings with a thickness of 500 mm, except at the centre, discharge from one heat exchanger, which rings are divided into two parts by other heat exchange elements in such a way that the distance of the new division surface from the heated pulp layer, or rather from the surface that was positioned against the other heat exchange surfaces, is approximately 250 mm. In other words, the pulp is divided into slices, which are then heated one at a time.

In closer examination, not even the indirect heat exchanger located inside the tower as disclosed in said

FI patent application 943001 has been proven reliable. For example, it has been observed that if a great number of separate annular heat exchange elements are located inside the tower, there is a great risk that the flow of the pulp will, at some points, be directed to the space between the heat exchange elements, so that a great deal of the heat exchange elements would not be made use of. In other words, at least in the light of current research, it seems that heating of the pulp by means of more than one heat exchange ring located within each other is not possible but that heating of the pulp would have to be performed in a separate apparatus which is smaller in size.

In addition, experiments have shown that the pulp layer with a thickness of about 250 mm is far too thick to be heated indirectly. The solution is to be found through treatment of much thinner pulp layers.

Thus, one object of the invention is to develop an indirect heat exchanger for heating or cooling pulp when the flow is a so called plug flow.

Another object of the invention is to develop a configuration by means of which the pulp can be heated or cooled to a desired temperature, and through which the pulp can be fed into a treatment tower or the like, equalizing at the same time the temperature of the pulp. Said object of the invention is implemented by means of an apparatus comprising an indirect heat exchanger, a mixing/feeding device and a treatment tower.

The characterizing features of an apparatus eliminating the disadvantages of the above-mentioned prior art apparatuses and achieving the above-described objects of the invention become apparent from the appended claims.

The present invention is a result from a long-term series of experiments which studies the behaviour of medium-consistency pulp and which has deepened the knowledge in the field to such an extent that it has become possible to develop apparatuses which, a few yers ago, no one would have believed to function. As an example of the research results, a heat exchanger can be mentioned in which medium-consistency pulp can be heated or cooled totally without a fluidizing apparatus, if desired. What makes the invention especially significant is the fact that the apparatus is industrially applicable at almost countless locations in a cellulose mill.

It is worth mentioning of advantages of the method and apparatus in accordance with the invention, part of which advantages were, of course, theoretically achievable by means of the apparatus in accordance with the FI patent application 943001, that

- the consistency of the pulp will not change when heating the pulp,
- the condensation water stays clear and can be recycled,
- neither the pressure of the reactor nor the temperature of the condenser needs to be limited according to the requirements for the steam,
- no large blow tank-pump-condenser combination is required,
- the pressure of the pulp in the reactor tower can be used for feeding the pulp to the next process stage, e.g. to a washer,
- for heating the pulp, low pressure steam may be used which is classified as waste in a cellulose mill, the removal, i.e. the condensation of which waste needs to be arranged in some way, too. By utilizing the amount of heat in the low pressure steam by means of an indirect heat exchanger in accordance with our invention it is

possible to sell out a larger part of the energy produced by the mill.

In the following, the method and apparatus in accordance with the invention are explained in more detail with reference to the appended figures, of which

Figures 1a and 1b illustrate a heat exchanger arrangement in accordance with a preferred embodiment of the invention,

Figures 2a and 2b illustrate a heat exchanger arrangement in accordance with a second preferred embodiment of the invention,

Figures 3a and 3b illustrate a heat exchanger arrangement in accordace with a third preferred embodiment of the invention,

Figure 4 illustrates a heat exchanger arrangement in accordance with a fourth preferred embodiment of the invention,

Figure 5 illustrates a heat exchanger arrangement in accordance with a fifth preferred embodiment of the invention,

Figure 6 illustrates a heat exchanger arrangement in accordance with a sixth preferred embodiment of the invention,

Figure 7 illustrates results from experiments performed by means of different heat exchangers,

Figure 8 illustrates a practical application of heat exchangers in accordance with a preferred embodiment of the invention,

Figures 9a and 9b illustrate a heat exchanger arrangement in accordance with a seventh preferred embodiment of the invention,

Figures 10a, 10b and 10c illustrate a heat exchanger arrangement in accordance with an eighth preferred embodiment of the invention.

Figure 11 illustrates a heat exchanger arrangement in accordance with a ninth preferred embodiment of the invention, and

Figures 12a - 12d illustrate a few arrangements for a heat exchange surface in accordance with preferred embodiments of the invention.

The basis for our invention is that a few properties of medium-consistency pulp previously not known precisely were determined with such preciseness that it was possible to optimize the operation of apparatuses applying these properties so that the apparatuses became industrially usable. Firstly, the thermal conductivity of the pulp, i.e. the ability thereof to heat or cool was determined. Surprisingly, in spite of the fact that in our earlier application 943001 it was believed that heating could be performed in a pulp layer with a thickness of about 250 mm, it was now observed that, practically, heat is only transferred to a distance of about 10 - 30 mm from the surface of the heat exchanger. The reason for this is that medium-consistency pulp contains a relatively small amount of free liquid, which, if there was significantly more of it in the pulp, would allow the pulp to whirl and thereby also the heat to get deeper into the pulp. However, medium-consistency pulp is all through the flow cross-section composed of a dense fibre net allowing no whirling by means of which the heat would get further away from the heat exchange surface. Also, the pulp contains air almost as much as free liquid, air being, in turn, a heat insulator. Also the fibre itself may be classified as a heat insulator, at least compared to water. In other words, heat will not be conducted very far from the surface of the heat exchanger. Naturally, a fluidizing heat exchanger described above is already known from the prior art, but it has been proven unfeasible because of the great energy consumption thereof. Thus, the only possibility will be

treatment of pulp which flows "economically" as a plug flow.

As another property of pulp, the flow thereof in different types of channels was studied, whereby it could be observed that in a conventional consistency range used in cellulose mills, i.e. in the range of 6 - 16 %, more precisely 10 - 13 %, the flow velocity of the pulp has to be in the range of 0.01 - 5 m/s, preferably between 0.1 - 1 m/s, and most preferably between 0.1 - 0.5 m/s. The experiments showed that if flow velocities below the minimum limit are used, the plug flow will stick to the flow channel in the first suitable place, whereby in another part of the plug the flow velocity increases, in other words, the result is channelling of the flow. Since channelling is affected by the cross-sectional area of the flow, it is possible to use very low velocities in very large cross-sectional areas, and vice versa. In other words, it is quite possible that the effective cross-sectional area of the flow channel is reduced to half, the flow velocity in this area is doubled and the pulp staying in the channel is gradually spoilt, or detached in lumps which are harmful for the operation of the apparatus. The experiments showed that flow velocities above the maximum limit are in practice impossible because of pressure losses. In other words, the energy consumption required by the transfer of pulp increases disproportionately.

At the next stage, the results of the above-described experiments were collected together, and it was noted that the length of the heat exchange surface in the flowing direction of the pulp should be approximately 10 - 70 cm in order to heat the above-mentioned pulp layer as effectively as possible. We have also observed that changes in the consistency in the area of medium-consistency pulp do not affect the length of the heat

exchange surface, since although pulp does not receive heat quite so effectively, the layer that does heat is correspondingly thinner, whereby heating is effected substantially within the same time.

Figures 1a and 1b illustrate a heat exchanger arrangement in accordance with one preferred embodiment of the invention. The heat exchanger in the figures is in this embodiment composed of a substantially cylindrical flow channel (channels with other forms of cross-section are also possible but hardly economically justifiable), i.e. tube 10, which may be (but not necessarily is) provided with heat exchange channel/s 12 encircling at least parts of the periphery thereof, preferably the whole tube 10. Inside the tube 10, heat exchange elements 14, 16 and 18 are arranged preferably on the diameter of the tube, which elements are located one after another inside the tube 10, as illustrated in Figure 1b. The elements are located in the tube preferably in such a way that they divide the pulp plug passing in the tube into two parts in such a way that the pulp plug becomes divided into equal sectors in the range of the whole length of the element group (in Figure 1a into sectors of 60 degrees in such a way that they form a star-shaped figure seen from the axis). Preferably, the elements are located closely one after another in such a way that there will be no substantial changes when moving on from the area of one element to that of another element. The heat exchange elements 14, 16 and 18 are preferably composed of two plates facing each other, between which plates there is a channel for a heat exchange medium. The shape of the channel may well be very flat, even rectangular, as illustrated in Figures 1a and 1b, whereby the heat exchange elements 14, 16 and 18 do not reduce the flow cross-section substantially. On the other hand, if pressurized steam is used as a heating medium, as is supposedly done in most cases, it is more preferable to

originally design the shape of the h at exchange element rounder, oval, or elliptical, which is a much more pressure-proof shape. Hereby, it is preferable, if not always necessary, to widen the outer dimensioning of the flow channel at the heat exchanger relative to the rest of the flow channel.

Figure 2b illustrates a cross-section of another preferred embodiment of the invention, in which a cross-section of heat exchange elements 214 and 216 is an oval. In other words, the elements are preferably composed of two curved plates placed face to face with each other and attached to each other by their edges, and of end surfaces located substantially vertically against the flow. The elements 214 and 216 preferably form a star-shaped figure seen from the axis, as illustrated in Figure 2a, which is a section A-A from Figure 2b. The elements 214 and 216 are, in turn, attached only by thin plates 230 or ribs, which may also be used, if desired, for conducting a heat exchange medium into a heat exchange element or out of it, or for conducting the condensate out to the flow channel 210 so as to ensure the most unimpeded pulp flow possible in the space between the elements 214 and 216 and the wall of the flow channel 210. In other words, the intention is to avoid a situation where an oval heat exchange surface would be almost tangentially joined with the wall of the flow channel, leaving a very narrow slot for a flow channel of the pulp, to which flow channel the thick stock would naturally stick, causing a reduction of the cross-sectional area of the flow channel, a reduction of the heat exchange surface, and probably also spoiling of the pulp at this location.

Furthermore, Figure 2b illustrates how the inlet tube 206 for the pulp leading to the heat exchanger has a smaller diameter than the flow channel 210 in the heat exchanger.

The cross-sectional area of the inlet tube 206 is preferably about the same as the cross-sectional area of the flow channel 210 of the heat exchanger when the cross-sectional area of the heat exchange element 214 or 216 has been subtracted therefrom. Even relatively great variations in the area may, however, be allowed in some conditions. In the embodiment of the figure, the cross-sectional area of the outlet tube 208 is the same as that of the inlet tube 206. If required, even this dimensioning may be changed, for example by throttling the diameter of the outlet tube 208 in such a way that more turbulence is generated in the flow so as to equalize the temperature. A corresponding effect may naturally be achieved by arranging ribs on the wall of the outlet tube, or other mixing elements in the tube 208 itself.

Figures 3a and 3b illustrate a heat exchanger in accordance with a third preferred embodiment of the invention, which heat exchanger is, in accordance with the preceding embodiment, composed of a flow channel 310 located between an inlet tube 306 and an outlet tube 308, and encircled with a space 312 for a heat exchange medium. The channel 310 is divided into four parts 322, 324, 326 and 328 in the flowing direction. Said parts 322 and 326 have the same diameter D, and, correspondingly, the parts 324 and 328 have the same diameter d, which is somewhat smaller than the diameter D. The idea with the variation of the diameter is that as the medium-consistency pulp flows as a plug in the channel, simultaneously heating, the surface layer of the pulp needs to be stirred from time to time to enable the access of the heat along with pulp particles deeper into the pulp, and correspondingly, to enable the transfer of cooler pulp to the vicinity of the heat exchange surface. Naturally, depending on the diameter of the whole flow channel, the difference between D-d may preferably vary

in the range of 50 - 300 mm, more preferably in the range of 50 - 200 mm. Naturally, it is desirable to perform the same kind of stirring in connection with cooling of the pulp. In the embodiment of these figures, four heat exchange elements 314, 316, 318 and 320, located one after another, are arranged inside the flow channel 310, which heat excange elements are attached to the flow channel by means of plates, ribs, or the like, as illustrated in the preceding embodiment. Figure 3a shows a star-shaped figure already known from the preceding embodiments.

Figure 4 illustrates a heat exchanger in accordance with a fourth preferred embodiment of the invention. The basis is the heat exchanger illustrated in Figure 2, which is, however, provided with ribs 440 at least on the surface 410 of the flow channel thereof, which ribs are in the embodiment of the figure located on the inner surface of the flow channel vertically relative to the axis of the heat exchanger. Naturally, the ribs may also, especially in such a situation as showed in the figure where the flow channel 410 is a preferably cylindrical tube being of the same length as the whole heat exchanger, be located spirally in the flow channel. The actual purpose of the ribs 440, i.e. achieving turbulence and through that agitation in the pulp, may, of course, be as well effected by means of other turbulence members than such ribs extending all through the periphery, for example by means of discontinuous ribs or many different types of pieces or pins. Also the cross-section of the rib may be very different from that illustrated in Figure 4. One example that can be mentioned is a rib in which the front surface receiving the pulp flow from the inlet tube 406 is right-angled, as illustrated in the figure, the outlet surface, in other words the surface on the side of the outlet tube 408 being, however, inclined, descending steadily onto the surface of the flow channel. The height

of the rib may vary between 10 - 50 mm, depending on the diameter of the flow channel.

In addition, as already mentioned earlier, the surface of the heat exchange elements may be provided with similar ribs. Figure 5 illustrates a heat exchanger corresponding to the embodiment of Figure 3, in which heat exchanger, however, each part 522, 524, 526 and 528 of the flow channel 510, as well as the heat exchange elements 314, 316, 318 and 320 are provided with ribs 540, 542 located substantially vertically relative to the axis of the heat exchanger. Naturally, the ribs may be replaced by other corresponding members contributing to agitation of the surface layer of the pulp, for example with protrusions or pins. The dimensions and forms of the ribs are described in more detail in connection with Figure 4.

Since according to our experiments, the conduction of heat from one piece of pulp to another is very slow in thick stock, it is preferable to stir the pulp from time to time efficiently enough to intensify heating. Figure 6 illustrates a heat exchanger 600 in accordance with a preferred embodiment of the invention, in which the two heat exchangers 602 and 604 are connected in series in such a way that a mixing member 650 is arranged in the tube 605 in the space between the heat exchangers. According to our experiments, the mixer does not have to fluidize the pulp, but it is sufficient that the pulp is "stirred" so that the pulp particles, no matter what their size at this stage, are effectively mixed with each other. The final result is, in any case, a pulp plug in a new order at the inlet of the heat exchanger 604, being distributed in a new manner to heat exchange surfaces of the heat exchanger 604. For example an apparatus like the one illustrated in the figure may be used as a mixer, having a circle or ellipse ring as a mixing member which

is driven by a special driving apparatus or, influenced by the flow, rotating in the flow.

Another embodiment as an alternative for connecting heat exchangers in series could be a solution in which a mixer arranged in the intermediate or connecting tube in Figure 6 is replaced with static members which generate sufficient turbulence to mix the pulp. In some cases, even reducing the cross-sectional area of the flow channel from one heat exchanger to the intermediate tube, and further, widening of the cross-sectional area from the intermediate tube to another heat exchanger is enough for achieving sufficient agitation. In such a case, it is also preferable to arrange the heat exchange elements in the first and the following heat exchanger/s optimally in such a way that the heat exchange elements form an evenly divided star-shaped figure when seen from the end of the heat exchange set. In other words, if two heat exchangers are connected one after the other, both having four heat exchange elements, i.e. heat exchange elements illustrated in Figures 3 and 5 or modified from these, it is preferable to turn one heat exchange element in such a way that the angle between the heat exchange elements seen from the end becomes 22.5 degrees.

Example 1

The purpose of the first experiment was to find out how deep, measured from the heat exchange surface, the heat will get, as the pulp flows in a plug flow in the channel. Another purpose was to find out how long the heat exchange surface should be in the direction of the flow, since it could be assumed that at a given flow velocity, there is such a heat exchange length after which pulp does not, practically speaking, heat at all.

A first prototype in accordance with the invention was a cylindrical tube encircled with a space into which heat

exchange medium could be brought. The diameter of the flow channel of the heat exchanger was 400 mm. No heat exchange elements were arranged inside the flow channel in the first prototype, since the intention was only to study the transfer of heat as a plug flow in flowing pulp.

When studying at first the transfer of heat in the tube in the radial direction, temperature sensors placed at different depths from the surface showed that there was a perceivable rise in the temperature only up to a distance of 20 - 30 mm from the heat exchange surface. The best comparable indication was received at a depth of 10 mm where the rise in the temperature was clear and the effect of the surface did not do any harm to the accuracy of the measuring.

It was already known from previous studies related to the flow of medium-consistency pulp that there is a given velocity for each diameter of the flow channel below which the flow tends to form channels. Correspondingly, it was known that the plug flow allows only a flow of given velocity at a given diameter of the flow channel. Hence, flow velocities between 0.1 - 5 m/s were used in our experiment. Already at the beginning it was observed that the flow velocity of 5 m/s was too fast, at least for the tube used in the experiment, and thus the flow velocity was then dropped to 1 m/s. In further experiments, flow velocities below 1 m/s were used. In the next experiment, it was especially the significance of the length of the heat exchange surface that was studied. The consistency of the pulp in the experiment was 10 - 12 %, the flow velocity in the flow channel of the heat exchanger being 0.1 - 1 m/s. The temperature sensor was at a distance of 10 mm from the heat exchange surface. Steam at a temperature of 160 °C was used as a heat exchange medium which was fed to the space

encircling the flow channel. The temperature of the pulp in the inlet tube was measured 40 - 65 °C. Correspondingly, the temperature of the pulp in the outlet tube was measured 42 - 66 °C. As a result, it was observed that in the mere tube the temperature of the pulp could be raised about two degrees at a distance of 10 mm from the surface of the tube, i.e. from the heat exchange surface, no matter how long the tube. Further, it was observed that at one flow velocity, when the length of the heat exchange surface was over 300 mm, the temperature of the pulp did not, practically speaking, rise at all any longer, at least not to such an extent that heating thereof could be regarded as industrially acceptable. Correspondingly, the length of the heat exchange surface being 100 - 200 mm, the pulp had had no time to heat to the effective maximum value thereof at the flow velocity used. The results of the performed experiment are shown in Figure 7 by means of a set of curves. The figure indicates that the slower the flow velocity (the flow velocity increases in the direction of the arrow V), the shorter the distance at which the temperature achieves the maximum value thereof. As the flow velocity increases, heating slows down and a need for a longer heat exchange surface increases. At the same time as the flow velocity increases, also the pressure loss, i.e. the flow resistance, increases, and therefore it has been concluded that when the length of the heat exchange surface is 200 - 500 mm, the greatest (the most macroeconomic) heating effect from the point of view of the overall system is achieved. However, also lengths of 100 - 700 mm may be used for the flow surfaces. In some cases, the lengths in the order of one, even two meters may be used, especially if there is nothing to restrict the length of the heat exchanger, whereby an apparatus which is more simply constructed and hence also less expensive may be acceptable. It has to be taken into account, however, that the temperature of the heating

medium, most often of steam, sets its own limitations, since a high temperature of steam together with a long heat exchange surface and a slow flow velocity may deteriorate fibres, especially when the pressure of the pulp in the flow channel is not sufficient to prevent boiling of the pulp.

Example 2

A heat exchanger in accordance with a preferred embodiment of the invention, the main features of which are illustrated in Figure 4, was tested in practice with medium-consistency pulp, using the measurement standards achieved as described above. The diameters of the inlet and outlet tube of the heat exchanger were 200 mm, the diameter of the flow channel of the heat exchanger was 400 mm and the length thereof 1000 mm. The widest diameter of the heat exchange element arranged inside the flow channel was 320 mm and the narrowest diameter 100 mm. There were two heat exchange elements in the heat exchanger used in the experiment. The consistency of the pulp in the experiment was 10 - 12 % and the flow velocity in the flow channel of the heat exchanger was 0.1 - 1.0 m/s. Steam at a temperature of 160 °C was used as a heat exchange medium, which could be fed both to the space encircling the flow channel and to the inside of the heat exchange element. The temperature of the pulp in the inlet tube was measured 40 - 75 °C. Correspondingly, the temperature of the pulp in the outlet tube was measured 50 - 85 °C. It was observed that by means of one element, a rise of about 5 °C can be achieved.

In Figure 8, a practical application of a heat exchanger in accordance with the invention is illustrated, in which application for example a heat exchanger 800 illustrated in Figure 6 is used to heat pulp to be fed to the tower 870. From another heat exchanger the pulp is discharged to a distributing feeding device 860, in which at the

same time as the pulp is evenly distributed to the whole diameter of the next tower 870, the temperature is equalized to be substantially constant throughout the pulp. If desired, the chemical required for a possible bleaching reaction in the tower may be fed into the pulp by means of a pump or a mixer located before the heat exchangers, or by means of a mixer located between the heat exchangers, or as late as in the distributing feeding device 860, or possibly by means of a mixer located after the heat exchanger, by means of which mixer the pulp may also be fed directly to the tower, if, for some reason, a distributing device 860 is not used. Naturally, it is also possible to use two separate heat exchangers connected with each other through a chemical mixer, for example, or just one heat exchanger connected to the tower through a mixer. In some cases, the equalization of the temperature may be performed by means of a pump with which the pulp is transferred from the heat exchanger to the next process apparatus. As regards other process variations, it is possible, and in many cases also preferable, to dispose the heat exchanger in a vertical position , for example adjacent to the bleaching tower. In particular, this could be applied to a two-step peroxide stage or a combination of an acid and a chlorine dioxide stage, in which pulp coming from a first reactor tower and to be fed to another tower is wished to be heated or cooled. Realized in this way, the heat exchanger may be constructed into an apparatus about 20 meters in length, which could be less expensive to manufacture than an apparatus the size of which is minimized.

Example 3

Figure 9 illustrates a method of taking care of the heating of pulp in practice by using h at exchangers presented in Figures 2 and 4. One possibility is to arrange two heat exchangers 802 and 804 one after the

other in the flow channel of the pulp, of which heat exchangers the diameter of the heat exchanger 802 is 1000 mm, for example. Thus, there is approximately 7 m^2 of heat exchange surface within the distance of one meter. This is because the periphery of the heat exchanger located on the surface of the tube is about 3 m, the area being thus about 3 m^2 as a one-meter long module, and because the two heat exchange elements located crosswise inside the tube, both being 0.5 m in length, have a heat exchange area of two times two square meters. In Figure 9, the heat exchanger 802 is connected directly to the heat exchanger 804, the diameter of which is twice as large, the heat exchange surface thereof being twice as large, too, i.e. 14 m^2, since it is based on a diameter of two meters.

Of course, it needs to be pointed out that the final form of heat exchangers is not, by all means, limited to the examples explained above, nor to the examples presented in the figures above, but that even significant amendments may be made to them without departing from the main idea of the invention. In other words, heat exchange surfaces may be added to the solutions described in the above embodiments for example in the form of fins attached to the wall of the flow channel in such a way that they are located between heat exchange elements. Figure 10a illustrates a heat exchanger 1000, in which there are members extending inward, so called fins 1011, arranged on the inner surface of the flow channel 1010, which fins increase the heat exchange surface significantly. The fins may be disposed in many different ways. In Figure 10, they are disposed in a heat exchanger the basic structure of which is like in Figures 2 and 4 in such a way that they divide the 90-degree sectors, seen from the end of the heat exchanger, between heat exchangers 1014 and 1016 into two parts. In this

embodiment, the fins extend to the whole length of the heat exchanger.

In accordance with another alternative illustrated in Figure 10b, fins 1011' are located at the tips of heat exchange elements 1014' and 1016' where they can also function as a channel introducing heat exchange medium to the heat exchange element. In accordance with the embodiment of the figure, none of the fins 1011' is longer than the heat exchange element at the tip of which it is located.

In Figure 10c, yet another alternative is presented, in which fins 1011'' divide the 180-degree sectors formed into their places in a flow channel 1010'' by heat exchange elements 1014'' and 1016'' into two parts at the periphery. Also in this embodiment the fins are only as long as the heat exchange elements in the vicinity of which they are located. Naturally, it is possible to combine the ideas of Figures 10b and 10c in such a way that the fins extend to the whole length of the heat exchanger, whereby they, along part of their length, support the heat exchange elements, and are, along part of their length, supported by the wall of the flow channel only.

Figure 11 illustrates yet another preferable constructional arrangement for a heat exchange element. A heat exchange element 1114 is preferably composed of two curved heat exchange surfaces 1150 facing each other, as becomes apparent from preceding figures. The walls may, of course, be totally plane-like or of some other suitable form. In the case where several elements 1114 are connected one after another the steam is preferably introduced to the element through a central opening 1152. In the interior of the element 1114, partition walls 1154 are arranged, by means of which walls the steam is made

circulate inside the element in such a way that an even temperature on the heat exchange surfaces can be ensured. Simultaneously, the partition walls 1154 effectively support curved surfaces against either steam pressure or pressure of the surrounding pulp, depending on which of these is higher. The steam may be removed in the way illustrated in the figure through a tube 1156, which may also be used to support the element on the wall of the flow channel. Correspondingly, below it, the element may be supported against the wall of the flow channel by a tube 1158, along which also the condensate is removed out of the element. The figure also shows how the lower ends of the partition walls are provided with openings to conduct the condensate from each chamber toward the tube 1158.

Figures 12 illustrate a few other alternatives in addition to the arrangements for heat exchange surfaces and heat exchange elements dealt with earlier, by means of which alternatives the channels or spaces for the flow of the heat exchange medium may be arranged on the wall of the flow channel itself, or by means of which it is possible to replace the heat exchange element having an elliptic cross-section form on the vertical plane relative to the flowing direction of the material, as presented in preceding embodiments, with a significantly thinner arrangement.

Figure 12a illustrates a so called finned tube wall as an example of various applications of heat recovery, which wall is known from for example walls of combustion chambers in power plant boilers, and which can be disposed in virtually any position. In other words, it is possible to arrange the tubes intended for the heat exchange medium either vertically, spirally turning or horizontally. No matter in what direction the tubes are arranged, there needs to be a feeding channel for the

heat exchange medium at one end of the tubes and a removal channel, i.e. a collecting tube at the other end, and naturally also conduits for the condensate, in case steam is used as a heat exchange medium.

Figure 12b illustrates a finned tube wall, which is intended to be located in such a way that the flow tubes for the heat exchange medium are positioned substantially in the flowing direction of the material. Attached to the tubes, there are, in addition to a so called fin connecting the tubes together, also ribs on both sides of the tube, whereby the heat exchange surface is substantially increased compared to the arrangement of Figure 12a.

Figure 12 c illustrates a solution in which the tubes of the finned tube wall are arranged on horizontal planes or in an inclined position. In other words, the ribs to be attached onto the tube wall are divergent from the tubes. Naturally, the ribs on the finned tube walls of both Figures 12b and 12c may be on one side of the wall only, and not necessarily on both sides, as illustrated in the figures.

Figure 12d illustrates a construction in which an annular space between two cylinders is divided by partition walls into a group of axial or possibly spiral channels through which the heat exchange medium flows from the inlet to the outlet. A construction like this may well be used as a flow channel itself, since relatively narrow channels ensure that the heat exchange medium keeps the whole heat exchange surface isothermal throughout. Correspondingly, the same kind of construction as plane-like can be used as a construction basis for a heat exchange element arranged inside the flow channel.

As regards the construction of a heat exchanger, should there be peroxide present, it is preferabl to cover the fins and other heat exchange surfaces to prevent decomposing of the peroxide. Otherwise, it is preferable to use such metal, or material generally, that endures the chemical and mechanical conditions present.

As can be seen from the above description, a totally new and previously unknown method and apparatus for heating pulp to be bleached have been developed. It has to be noted about the above-described solutions that the intention is only to give a view of a few preferred embodiments of the invention, the purpose of which embodiments is by no means to restrict our invention from what has been disclosed in the appended claims, which claims alone define the scope of our invention. Thus, it is obvious that all details presented in connection with either a heating or heat-recovering heat exchanger alone are naturally applicable to both objects.

CLAIMS

1. An apparatus for treating materials which conduct heat poorly, such as a medium-consistency fiber suspension, which apparatus is an indirect heat exchanger comprising a flow channel which is preferably a part of the heat exchange surface, in which flow channel at least one heat exchange element provided with a heat exhange surface is arranged, **characterized** in that members changing the flow cross-sectional area of the channel are arranged on the wall of the flow channel at given distances from each other.

2. An apparatus according to claim 1, **characterized** in that members changing the flow cross-sectional area of the channel are substantially arranged on the wall of the flow channel at given distances from each other.

3. An apparatus according to claim 1, **characterized** in that a cross-sectional area, or the form thereof, which is determined on a plane against the flowing direction of the material of the heat exchange element, changes step by step in the flowing direction of the material.

4. An apparatus according to claim 1, **characterized** in that the length of the solid heat exchange surface parallel with the direction of the flow in the flow channel and/or heat exchange element is less than two meters, preferably less than one meter.

5. An apparatus according to claim 1, **characterized** in that the length of the solid heat exchange surface parallel with the direction of the flow in the flow channel and/or heat exchange element is 100 - 700 mm.

6. An apparatus according to claim 4 or 5, **characterized** in that said solid heat exchange surfaces are

substantially limited by ribs disposed substantially against the flowing direction of the material and/or by wall parts changing the flow cross-sectional area step by step, and/or by end surfaces of the heat exchange elements.

7. An apparatus according to claim 1, **characterized** in that members are arranged on the surface of the flow channel and/or heat exchange element in order to stir the surface layer of the medium to be treated.

8. An apparatus according to claim 7, **characterized** in that said elements are ribs.

9. An apparatus according to claim 1, **characterized** in that the flow channel is encircled with a space for heat exchange medium.

10. An apparatus according to claim 1, **characterized** in that several heat exchange elements are arranged inside the flow channel.

11. An apparatus according to claim 1, **characterized** in that the heat exchange elements are substantially composed of two curved plates and ends between which a space for a heat exchange medium is formed.

12. An appratus according to claim 11, **characterized** in that said heat exchange elements have an elliptic cross-section form on a vertical plane against the flowing direction of the material.

13. An apparatus according to claim 10 or 11, **characterized** in that said heat exchange elements are disposed one after another in the flow channel in such a way that they form a star-shaped figure seen from the direction of the axis of the flow channel.

14. An apparatus according to claim 1, **characterized** in that the heat exchange elements are composed of a so called finned tube construction.

15. An apparatus according to claim 1, **characterized** in that the height of said members from the heat exchange surface is at least 10 mm, preferably over 25 mm.

16. A method of treating materials which conduct heat poorly, such as a medium-consistency fiber suspension, in an indirect heat exchanger provided with heat exchange surfaces, in which heat exchanger said material is heated or cooled, **characterized** in that the material is fed to the flow channel of the heat exchanger, in which the average velocity of the material is kept below 5 m/s, preferably below 1.0 m/s.

17. A method according to claim 16, **characterized** in that the material is a fiber suspension at a consistency of 6 - 16 %, the proceeding of which as a plug flow is ensured by keeping the flow velocity below 1.0 m/s.

18. A method according to claim 16 or 17, **characterized** in that a small part, preferably a thin layer of the material at a time is treated on the heat exchange surfaces.

19. A method according to claim 18, **characterized** in that at least the treated part of the material is exposed to mixing forces, by means of which at least partly new, untreated material is brougth to the heat exchange surfaces.

20. A method according to claim 16, **characterized** in that the material proceeding as a plug flow is split by means of heat exchange surfaces following each other in the flowing direction of the material in different places so

that the material becomes treated as throughly as possible.

21. A method according to claim 20, **characterized** in that the material is exposed to mixing forces at the same time as the material is split in another place.

22. A method according to claim 16, **characterized** in that the temperature of the material rises more than one degree per one length meter of the flow channel.

23. A method according to claim 16, **characterized** in that the average temperature of the material rises more than one degree per one solid heat exchange surface.

24. A method of treating material which conducts heat poorly, especially medium-consistency fiber suspension, i.e. pulp, **characterized** in that

- the pulp, the consistency of which is 5 - 20 %, is introduced to a flowing channel, in the inside of which at least one indirect heat exchange element is arranged,
- the pulp is allowed to flow as a plug flow in the channel, the flow velocity being below 5 m/s, preferably below 1 m/s,
- the temperature of the pulp is changed in the flowing channel by over 5 °C, and
- the pulp is withdrawn from said flowing channel.

25. A method according to claim 24, **characterized** in that

- the pulp is withdrawn from said flowing channel to a mixing apparatus, by means of which the temperature variations are equalized.

26. A method according to claim 25, **characterized** in that treating chemical is fed into the pulp through said mixing apparatus.

27. A method according to claim 25 or 26, **characterized** in that the pulp is fed from the mixing apparatus to another heat exchanger, wherefrom it is withdrawn.

28. A method according to claim 24 or 25, **characterized** in that

- the pulp is introduced to a feeding device, by means of which the pulp is evenly distributed to the tower, preferably to a bleaching reactor, and at the same time
- the temperature variations in the pulp are equalized by mixing the pulp in said feeding device.

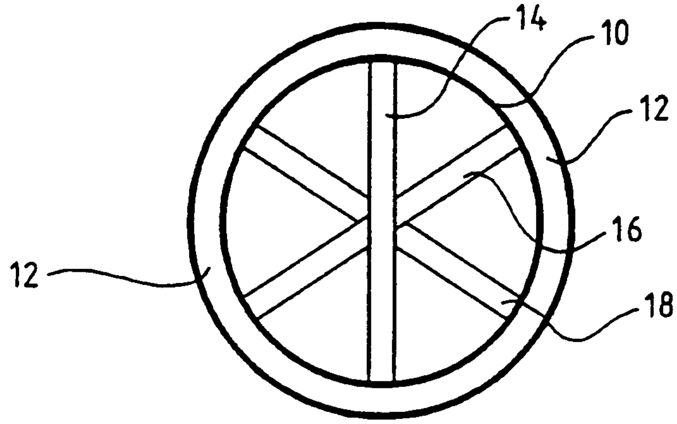

FIG.1a

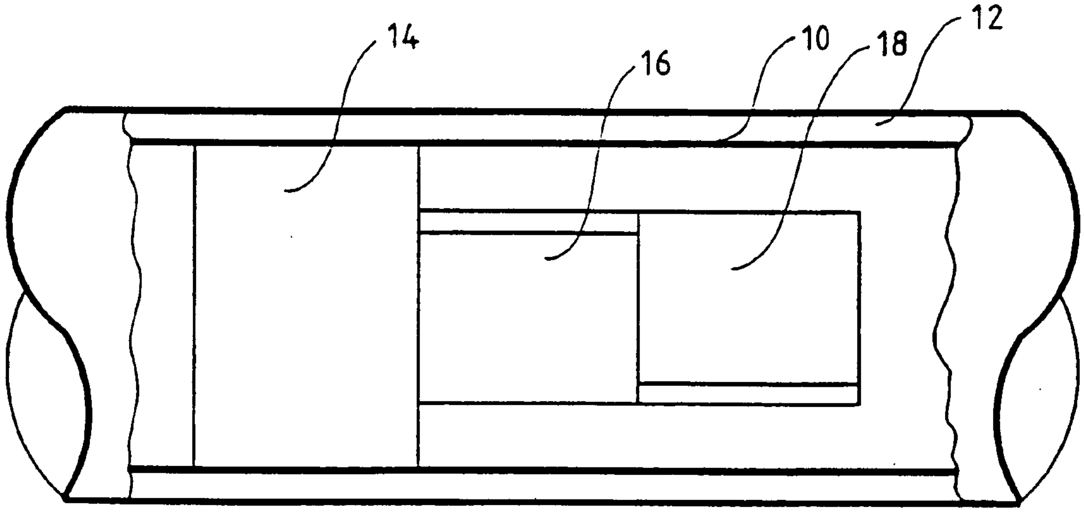

FIG.1b

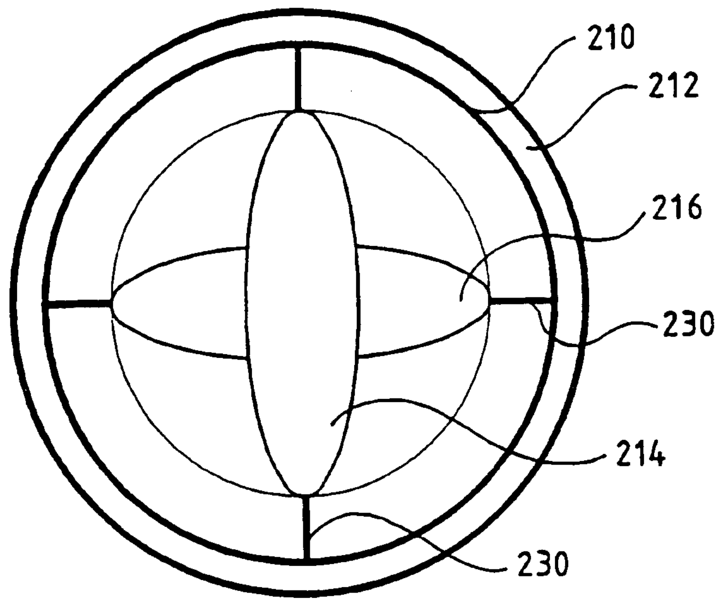

FIG. 2a

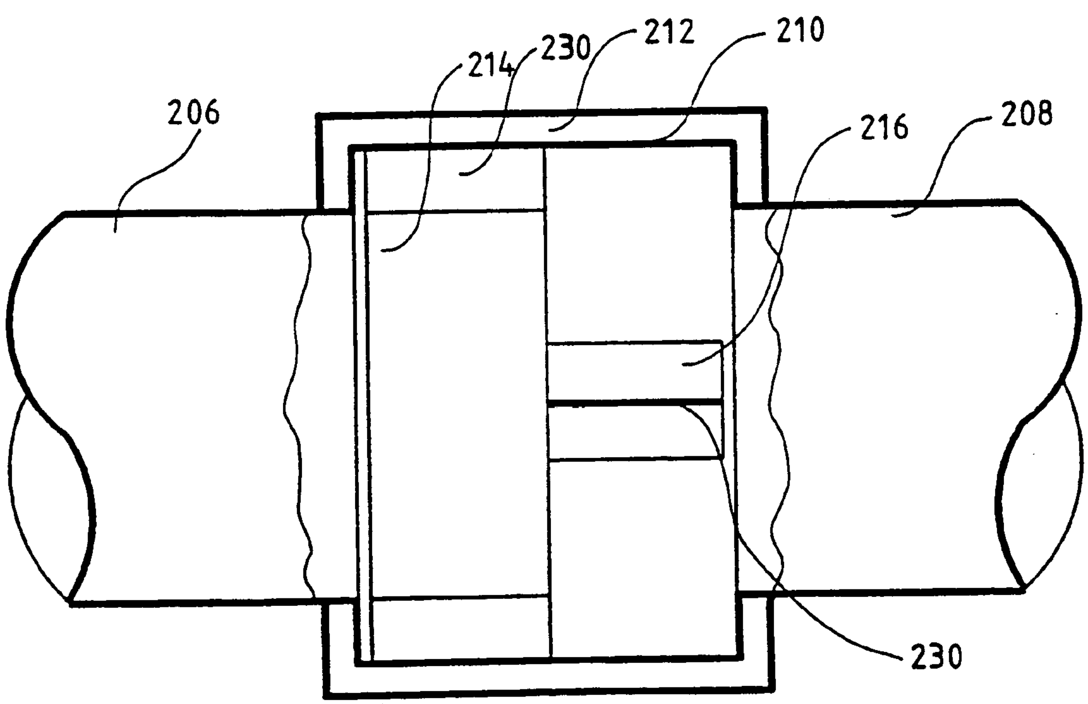

FIG. 2b

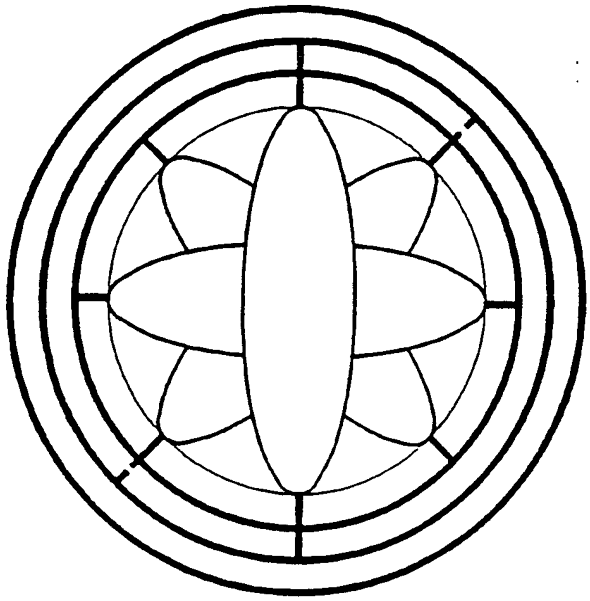

FIG. 3a

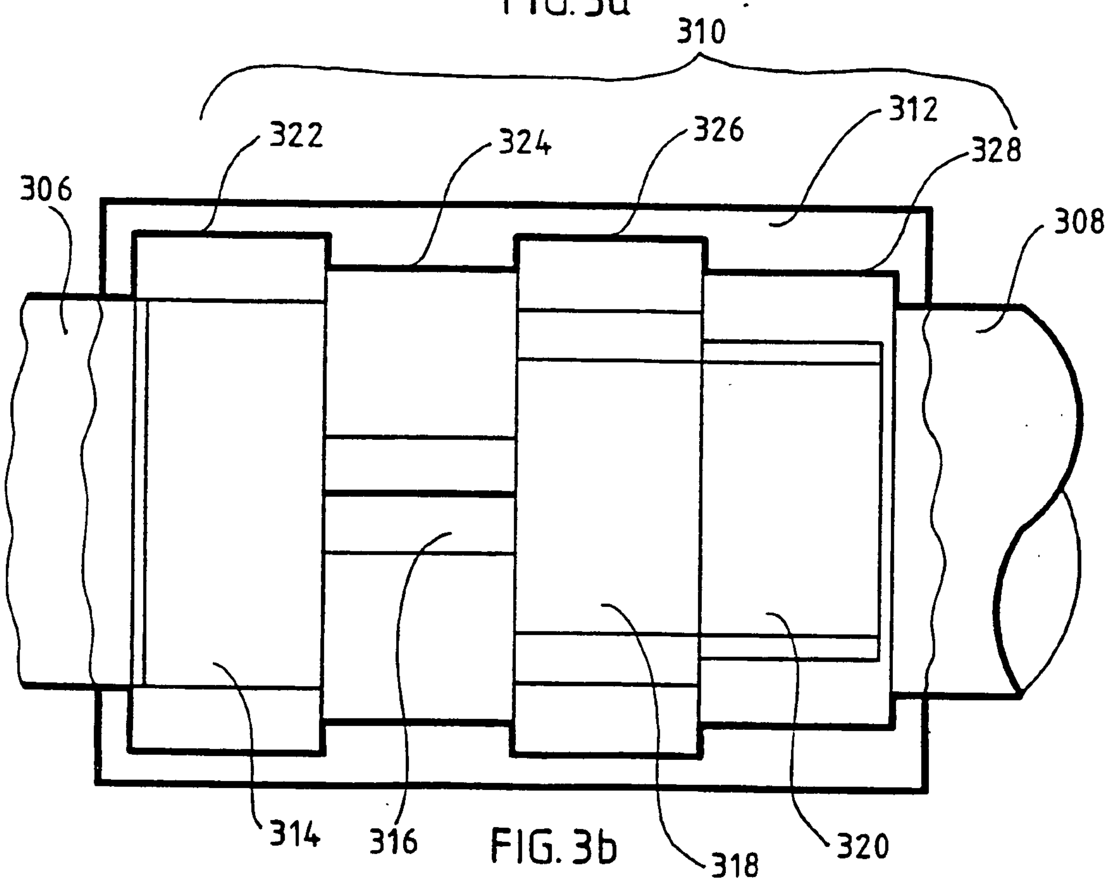

FIG. 3b

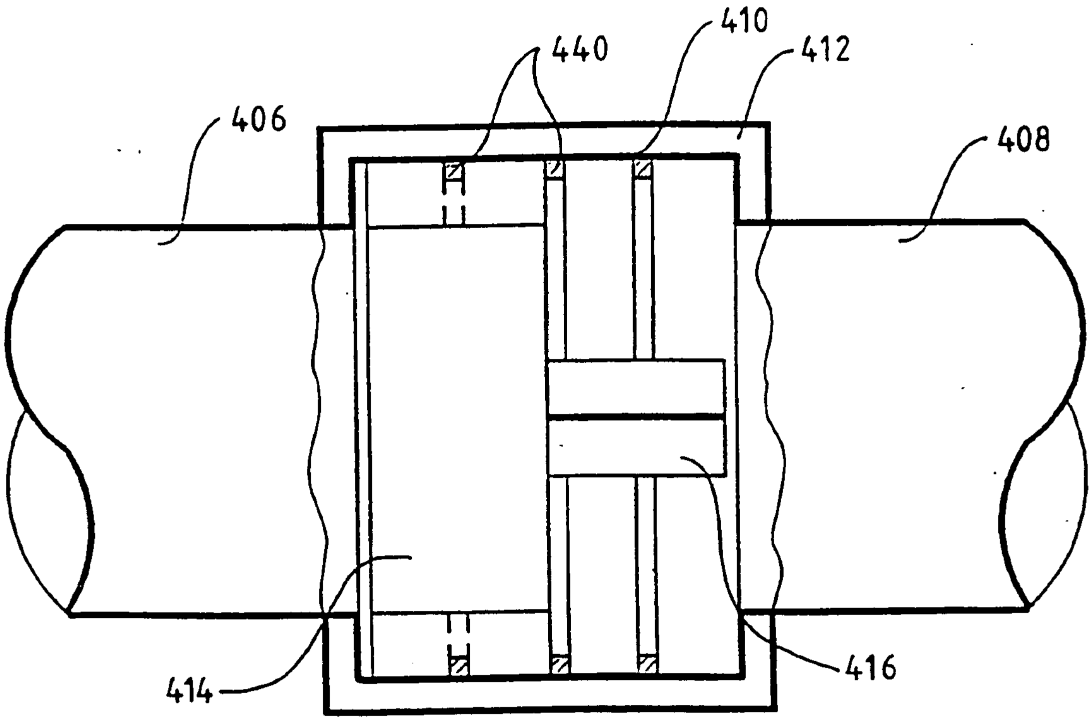

FIG. 4

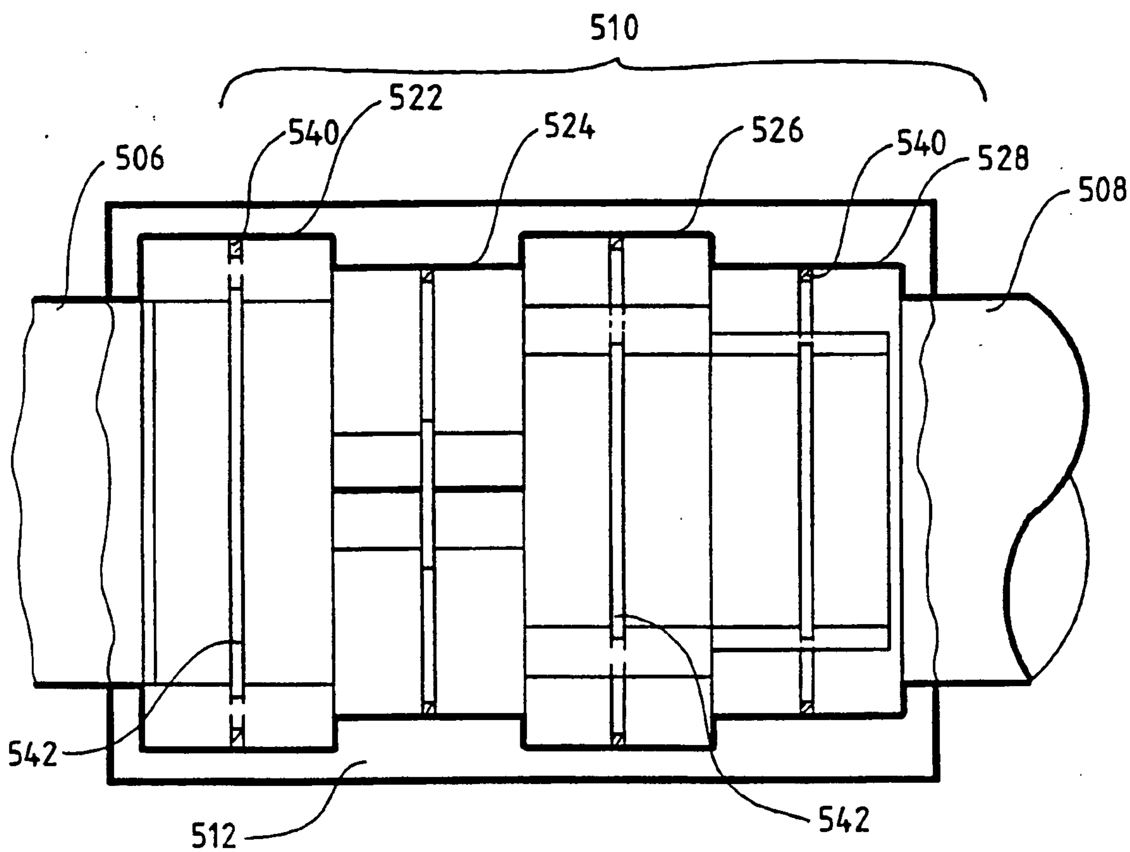

FIG. 5

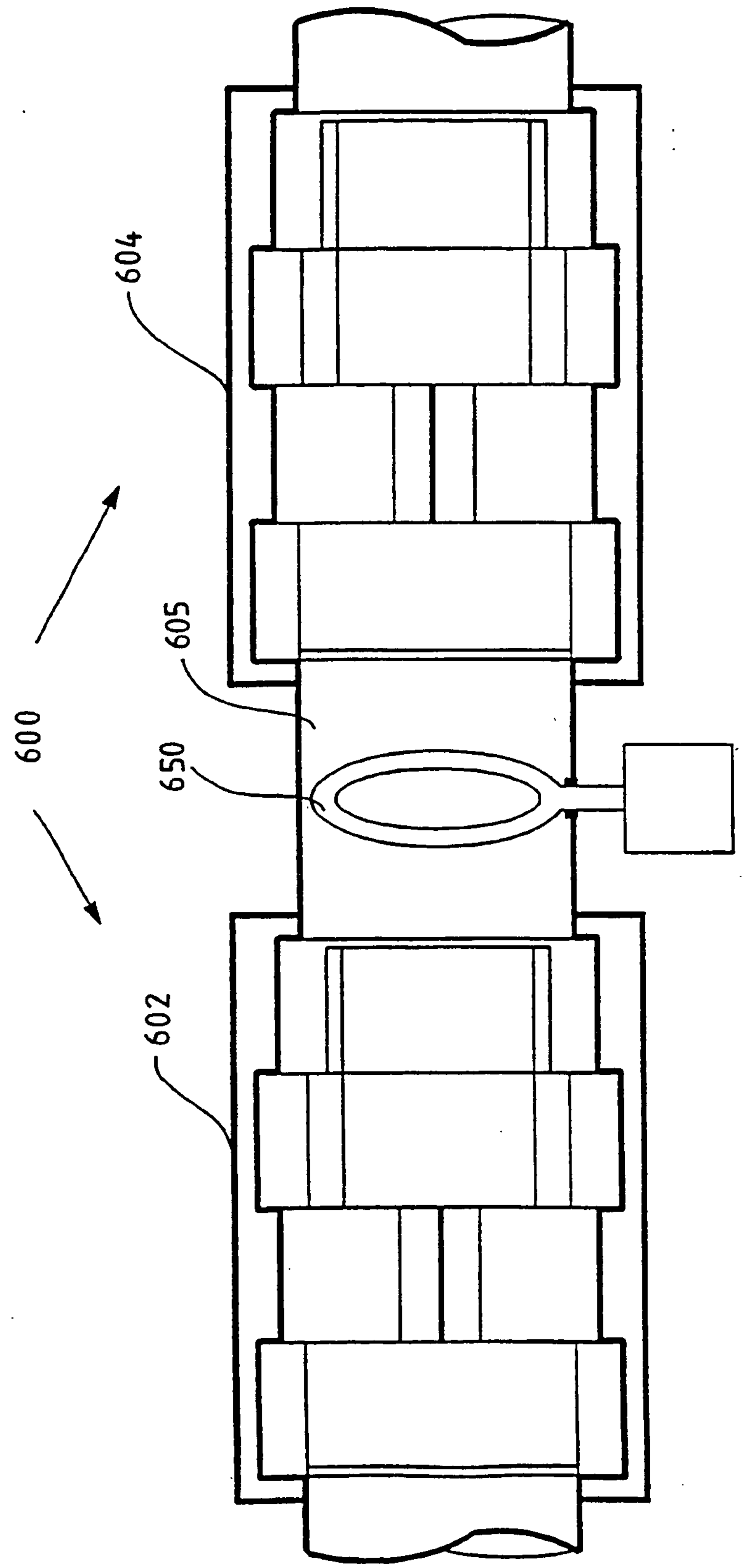

FIG. 6

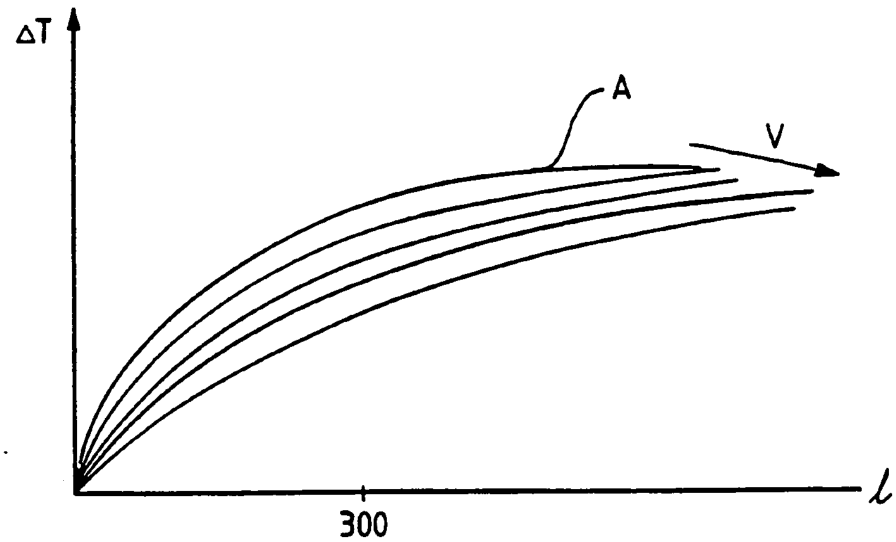

FIG. 7

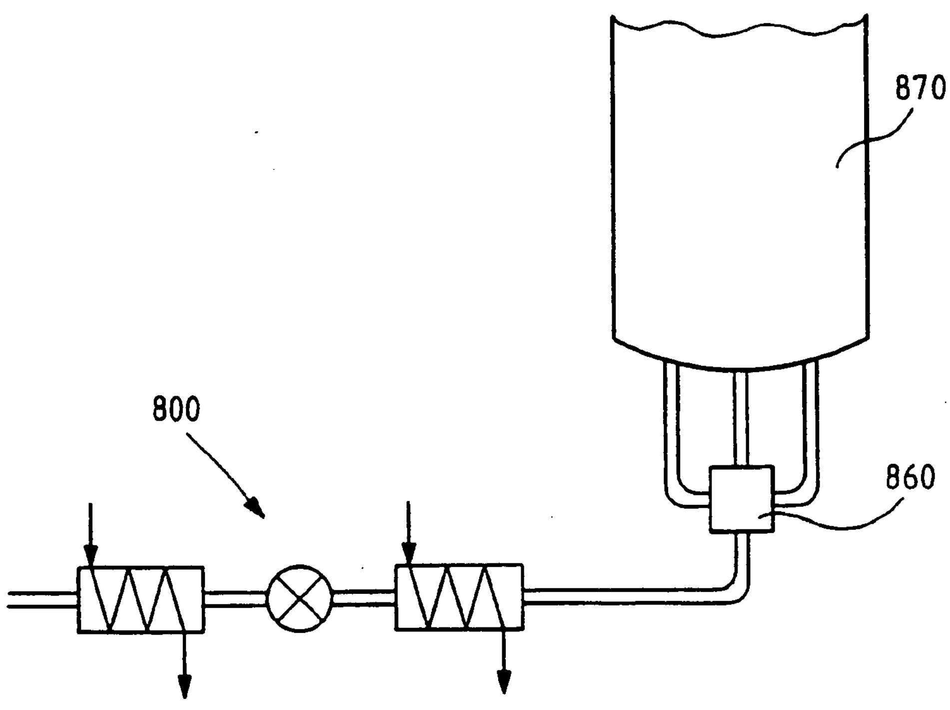

FIG. 8

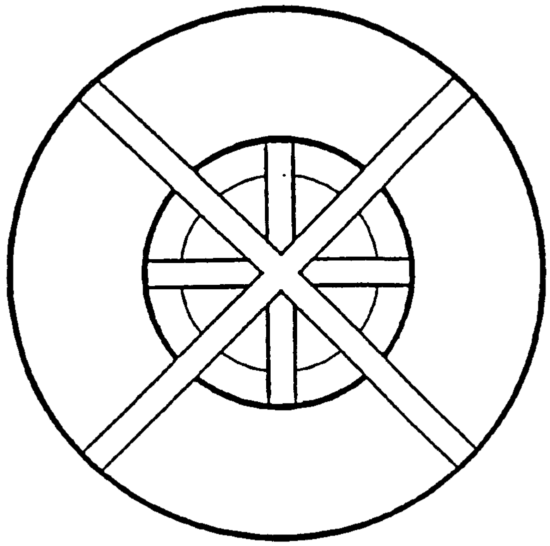

FIG. 9a

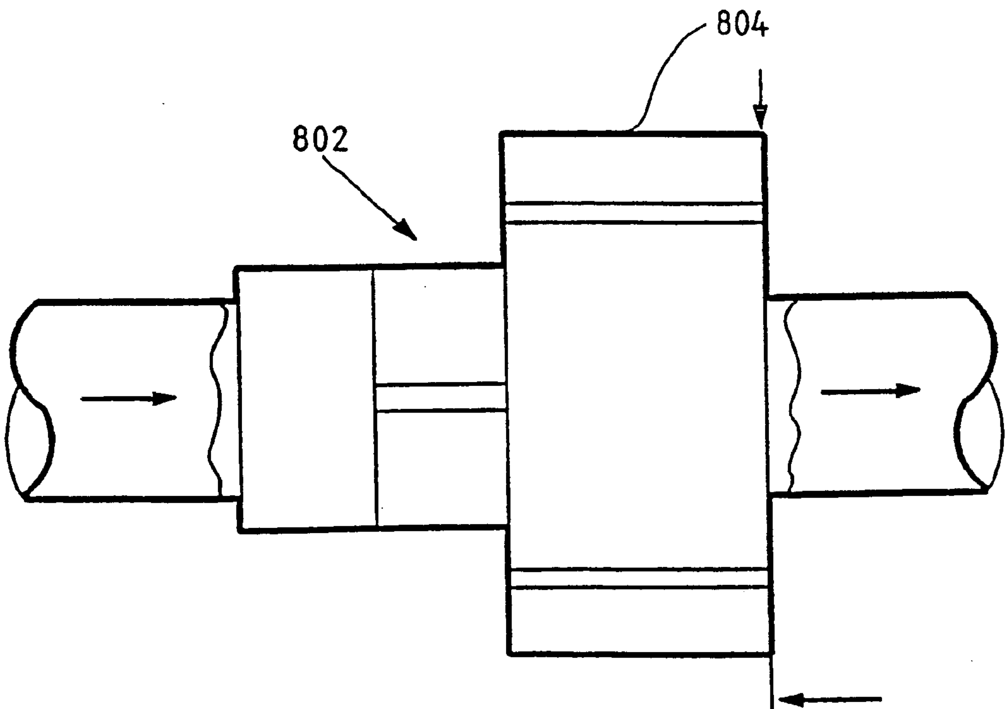

FIG. 9b

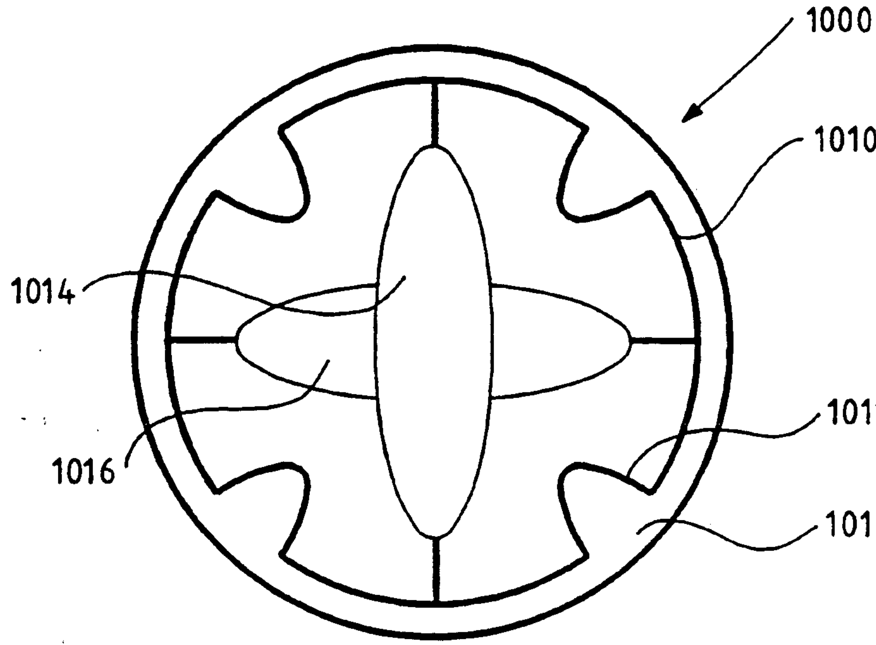

FIG.10a

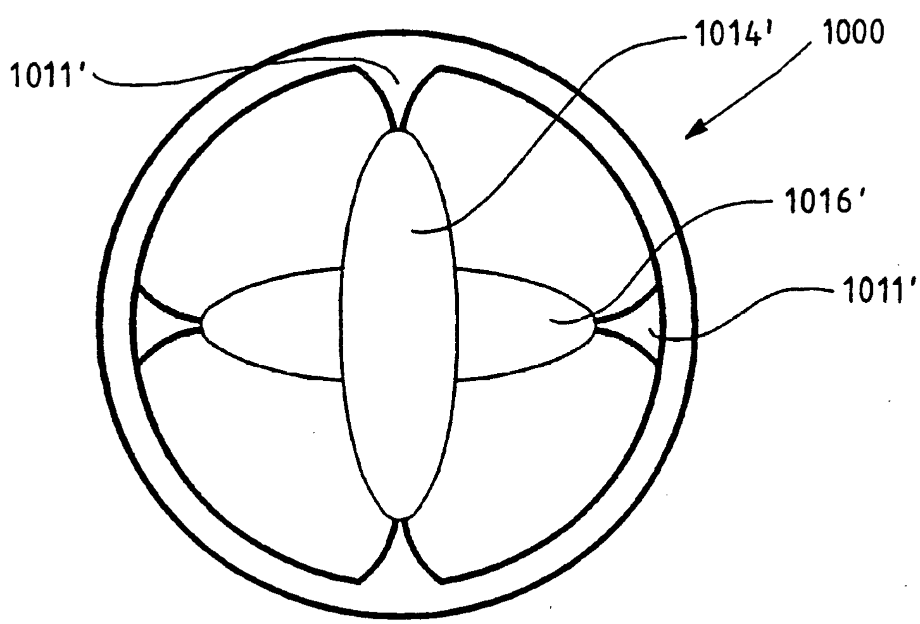

FIG.10b

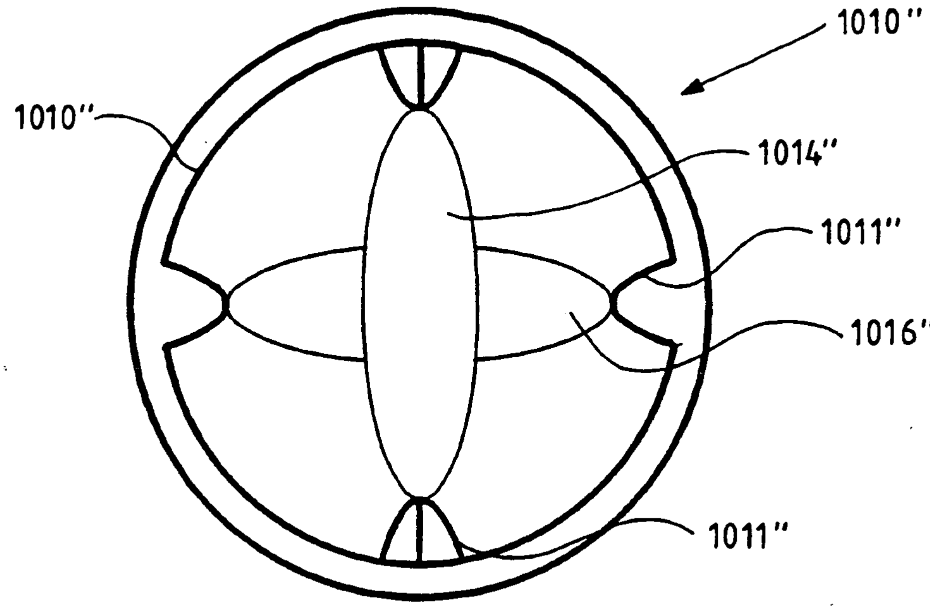

FIG.10c

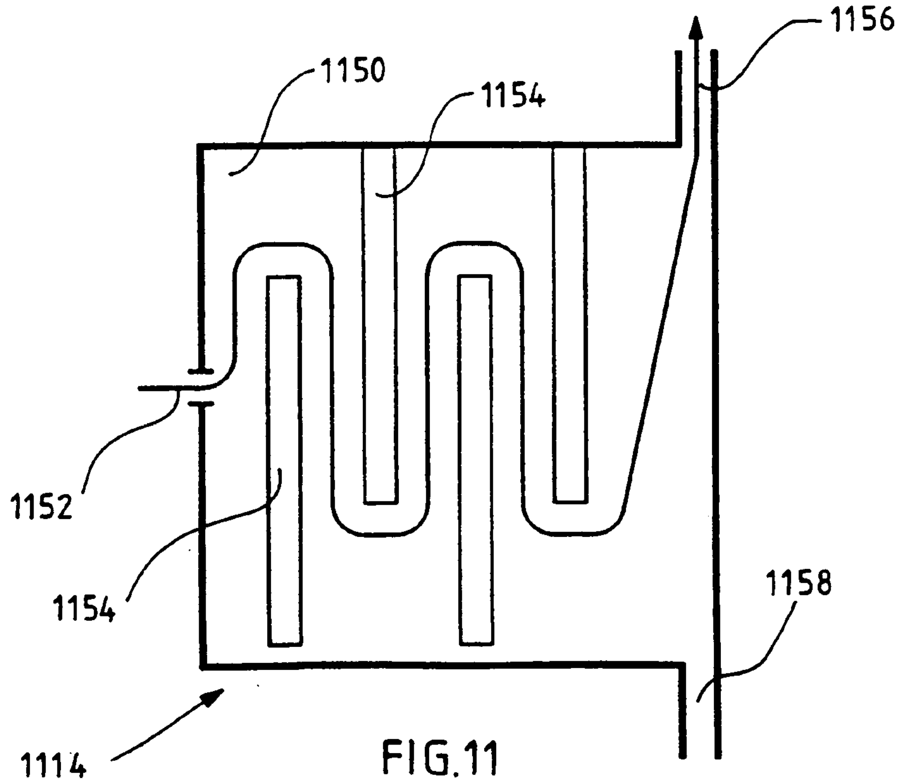

FIG.11

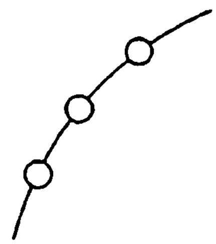

FIG. 12a

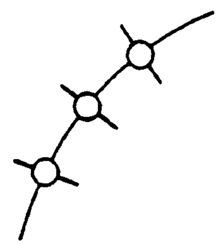

FIG.12b

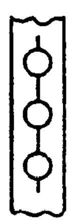

FIG 12c

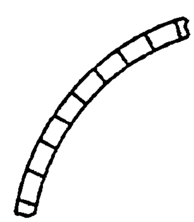

FIG.12d

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 96/00330

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F28F 13/06, D21C 9/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	GB 16948 A (CHARLES ALGERNON PARSONS, K.C.B.), 11 January 1912 (11.01.12), A.D. 1911 --	1,12-24
X	DE 1551512 A (SÖLCH, ROLAND), 21 May 1970 (21.05.70) --	1-8,14-24
X	US 4211277 A (F. GROSZ-RÖLL ET AL), 8 July 1980 (08.07.80) --	1-10,16-24

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 Sept 1996	24 -09- 1996
Name and mailing address of the ISA/ Swedish Pat nt Offic Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Magnus Thorén Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 96/00330

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	Derwent's abstract, No 88-166593/24, week 8824, ABSTRACT OF SU, 1352168 (ELCHINOV V P), 15 November 1987 (15.11.87) --	1-7,9,10, 16-24
X	Derwent's abstract, No 89-269588/37, week 8937, ABSTRACT OF SU, 1467363 (SUDAREV B V), 23 March 1989 (23.03.89) --	1-7,9,10, 14-23
A	US 3302701 A (D.G. THOMAS), 7 February 1967 (07.02.67) --	
A	EP 0275502 A1 (A. AHLSTRÖM CORPORATION), 27 July 1988 (27.07.88) -- --------	24-28

INTERNATIONAL SEARCH REPORT

Information on patent family members

05/09/96

International application No.
PCT/FI 96/00330

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EP-A1- 0412177	13/02/91	US-E- RE34255	18/05/93
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GB-A- 16948	11/01/12	NONE	
DE-A- 1551512	21/05/70	NONE	
US-A- 4211277	08/07/80	AU-B- 517032	02/07/81
		AU-A- 3665178	06/12/79
		CA-A- 1097335	10/03/81
		CH-A- 627263	31/12/81
		DE-A,C- 2808854	04/01/79
		FR-A,B- 2393258	29/12/78
		GB-A- 1603672	25/11/81
		JP-C- 1381926	09/06/87
		JP-A- 53148755	25/12/78
		JP-B- 61051239	07/11/86
		NL-A- 7804121	04/12/78
US-A- 4881596	21/11/89	EP-A,B- 0242838	28/10/87
		SE-T3- 0242838	
		JP-A- 63017394	25/01/88
US-A- 3302701	07/02/67	NONE	
EP-A1- 0275502	27/07/88	SE-T3- 0275502	
		DE-A- 3782154	12/11/92
		JP-C- 1602235	26/03/91
		JP-A- 63190086	05/08/88